This Page Is Inserted by IFW Operations
and is not a part of the Official Record

BEST AVAILABLE IMAGES

Defective images within this document are accurate representations of the original documents submitted by the applicant.

Defects in the images may include (but are not limited to):

- BLACK BORDERS
- TEXT CUT OFF AT TOP, BOTTOM OR SIDES
- FADED TEXT
- ILLEGIBLE TEXT
- SKEWED/SLANTED IMAGES
- COLORED PHOTOS
- BLACK OR VERY BLACK AND WHITE DARK PHOTOS
- GRAY SCALE DOCUMENTS

IMAGES ARE BEST AVAILABLE COPY.

As rescanning documents *will not* correct images,
please do not report the images to the
Image Problem Mailbox.

(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 0 883 042 B1

(12) EUROPEAN PATENT SPECIFICATION

(45) Date of publication and mention of the grant of the patent:
20.06.2001 Bulletin 2001/25

(51) Int Cl.7: **G05B 11/16**, G05F 1/56, H02P 7/05

(21) Application number: **98303186.5**

(22) Date of filing: **24.04.1998**

(54) On-off controller

Zeitpunktregler

Régulateur tout ou rien

(84) Designated Contracting States:
DE FR GB IT

(30) Priority: **05.06.1997 GB 9711630**

(43) Date of publication of application:
09.12.1998 Bulletin 1998/50

(73) Proprietor: **SWITCHED RELUCTANCE DRIVES LIMITED**
Harrogate, North Yorkshire HG3 1PR (GB)

(72) Inventor: **Elliott, Charles Richard**
Pudsey, West Yorkshire, LS28 5PS (GB)

(74) Representative: **Hale, Peter et al**
Kilburn & Strode
20 Red Lion Street
London WC1R 4PJ (GB)

(56) References cited:
EP-A- 0 769 844
GB-A- 2 305 313
US-A- 4 581 565
US-A- 4 959 602
US-A- 5 057 765

- **PATENT ABSTRACTS OF JAPAN vol. 018, no. 155 (E-1524), 15 March 1994 & JP 05 328800 A (NIPPONDENSO CO LTD), 10 December 1993,**

Note: Within nine months from the publication of the mention of the grant of the European patent, any person may give notice to the European Patent Office of opposition to the European patent granted. Notice of opposition shall be filed in a written reasoned statement. It shall not be deemed to have been filed until the opposition fee has been paid. (Art. 99(1) European Patent Convention).

Printed by Jouve, 75001 PARIS (FR)

Description

[0001] This invention relates to an on-off controller for a parameter, such as current, of an electrical load.

[0002] There are various methods of on-off control of parameter, such as current, in an electrical load. For example, the current output of a switched mode power supply or the torque output of a switched reluctance motor can be controlled by fixed off-time control or hysteresis control. These are examples of on-off or "bang-bang" controllers in which the control regime involves actuation of switch means between only the two basic states of on and off.

[0003] US-A-4959602 discloses a motor drive in which the current in a motor winding is ON-OFF controlled within hysteresis bands on either side of a reference current level. When the winding current exceeds the reference current it is only switched off once it reaches the upper boundary value of the hysteresis band and remains off until it reaches the lower boundary value.

[0004] JP-A-05328800 discloses a current controller for a generator in which an exciting coil current is controlled by switching it off once it has reached a set value and a fixed delay has elapsed.

[0005] EP-A-0769844 discloses a current control circuit which uses a low pass filter to average out the current signal. This is compared with a command signal and the error between them is turned into a pulse width modulated output that is used to actuate current control switches. A switched reluctance motor is often controlled by regulating the phase current in the or each phase winding at low speed. This is referred to as current-fed control. As a practical matter, a voltage regulated supply is normally available so an intermediate current controller is used. The controller actuates power switches to apply the voltage across the or each phase winding of the machine to establish and maintain the desired phase current.

[0006] A description of switched reluctance machines and their control can be found in the article 'The Characteristics, Design and Applications of Switched Reluctance Motors and Drives' by Stephenson and Blake, presented at the PCIM '93 Conference and Exhibition at Nurnberg, Germany, June 21-24, 1993.

[0007] Both the transient and steady-state responses of the controller will be affected by the characteristics of the electrical load that the phase winding represents. For example, the phase circuit of a switched reluctance motor has neither a constant inductance nor a simple 'motional EMF' effect. A simplified mathematical expression for the voltage across a phase circuit of a switched reluctance motor is :

$$v = iR + l(i,\theta)\frac{di}{dt} + i\omega\frac{\partial L}{\partial \theta}(i,\theta) \qquad (1)$$

where:

v is the phase voltage
R is the phase resistance
i is the phase current
L is the phase inductance
l is the incremental phase inductance
ω is the rotational speed
θ is the rotor angle relative to the stator
t is time

[0008] The three different terms in Equation 1 may be explained as follows :

the first term (iR) is that due to the resistive voltage drop in the phase winding;

the second term ($l(i,\theta)di/dt$) is proportional to the rate of change of phase current and is due to the effective inductance of the phase, i.e. the incremental inductance. This term can be seen to be non-linear in nature as the incremental inductance is a function of both current and angle. A plot showing the variation in the incremental inductance of a sample switched reluctance machine is shown in Figure 1 of the drawings which is a graph of incremental inductance against rotor angle for various values of phase current. This shows that incremental inductance can vary by over 10 to 1 for a machine operated over a wide range of currents, for example a servo-drive;

the last term of Equation 1 ($i\omega\partial L(i,\theta)/\partial\theta$) can be seen to be proportional to the rotational speed (ω) and is therefore sometimes called the 'motional EMF'. It arises because the phase inductance is a function of rotor angle and therefore varies with time as the machine rotates. It is also non-linear in nature and depends on how the phase inductance varies with rotor angle at a particular phase current and rotor angle. By way of illustration, Figure 2 shows the motional EMF for a switched reluctance machine for a given speed and various values of phase current.

[0009] Many different types of current control schemes are used with switched reluctance machines. For example, fixed off-time current control is often used because it is capable of high bandwidth control and simple implementation. The simplicity is based on the fact that only the switch current need be monitored for feedback, as opposed to the phase winding current. Fixed off-time control functions by switching off the voltage for a prescribed period whenever the current reaches a predetermined demand level. After the off-time interval, the voltage is re-applied by actuating the switches of the converter. While the switches of the converter are non-conducting, knowledge of the phase current is not available, but in many applications this is not a disadvantage.

[0010] Figure 3 shows the basic elements of a conventional off-time controller using a fixed off-time. The current to be monitored is fed to a current transducer

14, which can be of any known type. The output from the current transducer is passed through a noise filter 30 to remove spurious signals which may be present in the current transducer output, due to, for example, the switching action of the converter. In some commercial implementations, current transducers will have an integral noise filter. In either case, the amount of filtering is chosen so that the noise is suppressed without introducing any significant delay into the feedback signal. The output of the noise filter is a signal i_f, representative of the current to be controlled. This signal is fed to a comparator 10 which also receives a signal i_d representative of the demanded current. The comparator is arranged to output a signal it which changes state when the feedback signal i_f exceeds the demand signal i_d.

[0011] The output of the comparator i_t is applied both to the reset input of a set-reset flip-flop 22 and to a pulse generator 20 which applies a pulse to the set input of the flip-flop a fixed time, t_{off}, after the output of the comparator 10 indicates that the load current has reached the demanded level. The output of the flip-flop is, therefore, a signal which can be used to enable a power converter or other device (not shown) so that it applies current to a load. When the current in the load reaches the demanded current, the output of the comparator changes state.

[0012] Where the load is linear, this switching strategy results in a current waveform like that shown in Figure 4.

[0013] The rise and fall of current is depicted as linear and subject to voltages across the winding of the same magnitude but opposite polarity. With these assumptions an expression for the average current can be derived as:

$$i_{av} = i_d - \frac{\Delta i}{2} \text{ where } \Delta i = \frac{(V+i_{av}R+\varepsilon)t_{off}}{l} \qquad (2)$$

where:

i_{av} is the average phase current over the switching cycle.
i_d is the demanded phase current
Δi is the current excursion during the off time
V is the DC link voltage
R is the phase resistance
ε is the 'motional EMF'
l is the incremental inductance

[0014] The rise and fall of the current is, of course, not generally linear in practice. However, provided that the switching period is short compared with the time constant of the phase circuit, the error due to this approximation is often acceptably small.

[0015] It should be noted that, in this context, there may be a difference between the average current calculated over many switching cycles and the average current calculated over a few switching cycles. This can arise because of the nonlinearities referred to earlier or because of the demanded current changing over the phase cycle of the machine. In the description which follows, the term "average current" refers to the average over a few switching cycles.

[0016] From Equation 2 it can be deduced that the difference between the average phase current and the demanded current will vary according to the particular circuit characteristics. In many cases, the discrepancy is acceptable. When the phase current excursion from the demanded level is small, and/or an outer control loop governs the final motor output, the discrepancy can be compensated for. However, in other situations the discrepancy cannot be tolerated, for example, in applications where the phase current is required to be accurately profiled over a complete conduction cycle.

[0017] In fixed off-time current control of a non-linear electrical load, such as a phase of a switched reluctance motor, a variable error occurs in the average current. While this may be acceptable in some applications, higher performance applications will involve increasingly rapid changes in current that cannot be addressed adequately by an outer control loop because it is likely to introduce an output ripple in attempting to eradicate the error in the average current.

[0018] The same is generally true of other forms of control, such as hysteresis current control.

[0019] It is an object of the invention to reduce the error between the demanded parameter and the average parameter in a load controlled by on-off control.

[0020] According to the invention there is provided a method of on-off control of a parameter of an electrical load, the method comprising: setting a demanded parameter value; applying a voltage across the load by actuating switch means to initiate a changing parameter in the load; and removing the voltage from the load after a delay following the parameter reaching the demanded parameter value, such that the parameter exceeds the demanded value, the value of the error between the average parameter and the demanded value being reduced as a result, characterised in that the duration of the delay is derived from a period for which the voltage was previously applied across the load.

[0021] The delay may be equal to the said period for which the voltage was previously applied across the load.

[0022] In a particular form, the method may include comparing a demand signal indicative of the demanded current with a feedback signal indicative of a load current to produce an output signal having two states; producing a switch means deactuation signal in response to the output changing state; and delaying deactuation of the switch means by the deactuation signal for the period of the delay.

[0023] In another form, the method may include generating a feedback signal indicative of a current in the load; low-pass filtering the feedback signal; and comparing a demand signal indicative of the demanded current value with the feedback signal to produce a switch means deactuation signal in response to the feedback signal, whereby delaying actuation of the switch means by the deactuation signal.

[0024] In a further alternative form, the method may include determining the actuation period for which the switch means are actuated; and setting the deactuation period for which the switch means are subsequently deactuated in response to the actuation period. In this form the deactuation period is substantially equal to the actuation period. The actuation period may be determined by initiating one count in one direction from one value at the start of the actuation period and the deactuation period is set by initiating another count in the other direction from the value at the end of the one count to the one value. The method may also include setting a maximum actuation period; comparing the determined actuation period with the maximum actuation period; and reducing the deactuation period if the determined actuation period exceeds the maximum actuation period. In this case the deactuation period may be reduced to a predetermined value.

[0025] The invention also extends to an on-off controller for a parameter of an electrical load, the controller comprising: switch means actuatable to control the supply of electrical power to the load; demand means for producing a parameter demand signal; means for producing a parameter signal that is indicative of the parameter of the load; means for deriving an error signal from the demand signal and the parameter signal; control means arranged to receive the error signal and to produce one actuation signal for the switch means of a duration to reduce the error when the error signal exceeds a predetermined value and to produce another actuation signal for the switch means otherwise; and delay means operable to delay the one actuation signal when the error signal exceeds the said demand value, the value of an error between the average parameter value and the value indicated by the parameter demand signal being reduced as a result of the delay, characterised in that: the delay means are responsive to the duration of the other actuation signal to determine the period of the delay of the one actuation signal.

[0026] According to the invention a delay can be introduced in the controller such that the system compensates for the errors which are inherently present in an on-off controller. This goes against conventional wisdom that control systems generally work better by eliminating delays in the processing.

[0027] The invention can be put into practice in various ways some of which will now be described by way of example with reference to the accompanying drawings, in which:

Fig.1 is a graph of incremental inductance against electrical angle of a switched reluctance machine over half a cycle of the inductance period for various phase current values;

Fig.2 is a graph of motional emf against electrical angle of a switched reluctance machine over half a cycle of the inductance period for various phase current values;

Fig.3 is a schematic block diagram of a conventional, fixed off-time controller;

Fig.4 is a graphical illustration of phase current switching for a conventional, fixed off-time controller;

Fig.5 is a schematic block diagram of an off-time controller using fixed delay;

Fig.6 is a graphical illustration of phase current switching for the off-time controller of Fig.5;

Fig. 7 is a schematic block diagram of an embodiment of an off-time controller according to the invention, using variable delay; and

Fig.8 is a schematic block diagram of another embodiment of an off-time controller according to the invention, using variable delay.

[0028] While in general terms a control system is generally considered to be improved by reducing or eliminating time delays in feedback loops, this invention recognises that, by inserting a time delay within the feedback loop, the error between the demanded and the actual average current which normally occurs in a fixed off-time controller can be greatly reduced and, in some instances, virtually eliminated. By inspection of Figure 6 and of Equation 2 above, it will be seen that the time delay required to eliminate the steady state error is:

$$t_{delay} = \frac{(V + iR + \varepsilon)}{(V - iR - \varepsilon)} \cdot \frac{t_{off}}{2} \qquad (3)$$

The time delay can be of fixed duration, but there will be further advantage if it is of variable duration, preferably such that the duration is linked to the rate of rise of current.

[0029] Figure 5 shows a schematic block diagram in which a fixed delay is introduced into the feedback loop of an off-time controller. As stated above, the off-time controller is a form of on-off controller which is capable of only an on state and an off state as opposed, for example, to a controller which is able to produce a control signal value that is a function of the error between a demand signal and an actual value of the parameter.

[0030] The controller comprises a comparator 10 that receives an input signal i_d indicative of a current demand and a feedback signal i_f indicative of the phase current in the phase winding of a switched reluctance machine 12. The signal i_f is supplied by a sensor in the form of a current transducer 14, through a suitable noise filter 30. The output of the comparator is a switch actuation signal i_t that is applied to a turn-off delay circuit 18. The output of the delay circuit 18 is applied to an off-time pulse generator 20 that provides a pulse after the fixed off-time appropriate to the application has expired. The output of the delay is also applied directly to the reset input of a set-reset flip-flop 22 which produces a switch firing pulse T which is supplied to a power converter 34. The power converter functions to activate selectively the power switches of each phase circuit of the motor 12, according to known art, so that current is controlled in the phase winding.

[0031] If if is less than i_d, the comparator will output a switch turn-on signal i_t that is unaffected by the presence of the delay circuit 18. The signal i_t enables the firing signal T in a phase conduction period. Eventually, the signal i_f will reach the value of the demanded current, i_d. At this point, the output of the comparator will change to a switch turn-off signal. However, the turn-off signal will only be relayed by the delay circuit 18 after the delay period has elapsed. After the delay, the turn-off signal is applied to the flip-flop 22 resetting it and causing the switches in the power converter to be opened. The current then begins to fall. After the predetermined off-time has expired (determined by the off-time pulse generator 20) the flip-flop is set and the switches in the power convertor are closed. It will therefore be seen that the current in the phase winding will fall for the predetermined duration and, at the end of the off-time, assuming the phase current has fallen below the demanded level, the power switches will again be turned on to re-apply the voltage until the demanded current is again reached.

[0032] Figure 6 illustrates the phase current I_{ph} rising to the demanded level i_d and continuing to rise as the deactuation of the switches is delayed for the delay period t_{delay}. After the delay, the switches are de-actuated to initiate a falling current for a predetermined off-time t_{off}. At the end of the off-time, the switches are again actuated to cause the current to rise and the switching cycle repeats.

[0033] A constant off-time delay is introduced into the current control loop. The delay circuit could be either an analogue or a digital arrangement triggered by the phase current reaching the demand. A typical value for t_{delay} is half the off-time. The delay could also be effected as a common part of the circuit of the off-time pulse generator 20, depending on the value of time delay required and the implementation chosen.

[0034] Figure 7 illustrates an embodiment of the invention in which some parts have the same reference numerals as their equivalents in Figure 5.

[0035] A low pass filter 32 is connected between the output of the noise filter 30 and the input to the comparator 10. This creates a delay sufficient to cause the actual current to overshoot the demanded current and hence reduce the average error. This is due to the lag which the additional filtering introduces between the current feedback signal and the actual phase current. The amount of the lag will vary according to the characteristic of the additional filtering and the slope of the phase current. Care must be taken to ensure that the additional filtering does not cause instability or other incorrect operation of the current control. In some circumstances the additional filtering may be combined with conventional filtering used to reduce electrical noise which allows correct operation of the current control. This technique could therefore be implemented by reducing the cut-off frequency of existing filtering used to remove noise. The turn-off delay introduced would only be an approximation to that required to eliminate the error, but with the correct choice of filter this technique can significantly reduce the error over a large part of the operating range. Typical values for the low-pass filter would be $R = 1k\Omega$ $C = 1nF$ for an off-time of $40\mu sec$. In effect, this embodiment provides a variable turn-off delay dependent on the rate of rise of the feedback signal.

[0036] In a second embodiment, shown in Figure 8, the off-time is variable and is chosen according to the rate of rise of current. The circuit is arranged to include an up/down counter 36, which has an integral zero-count detector, receiving the output i_t of the comparator 10. The output of the counter is applied to the pulse generator 20 and the flip-flop 22. The remaining circuit components are arranged as in the previous embodiments and have the corresponding reference numerals.

[0037] After the off-time of a previous cycle is concluded, the switch signal T is produced by the flip-flop 22 in the previously described manner, the voltage is applied to the load and the up/down counter is reset. The counter the begins to count up. When the comparator detects that the demanded current has been reached and changes its output state, the output is applied to the counter 36 to cause the count to go in the reverse direction. The length of the count is the effective delay before the output of the flip-flop 22 is changed. At the end of the reverse count the zero-count detector causes the output of the counter to go high.

[0038] In this way, and provided the phase current parameter variations take place slowly compared with a switching period, the phase current waveform is automatically symmetrical about the demanded current. The steady state error will be substantially eliminated. Time delays in the control loop to do with sensing the current, detecting that the demanded current level has been reached and delays in controlling the switches will cause a small steady-state error in practice, but these can be factored out in the overall control system using known techniques.

[0039] This period measurement and adjustment works in a desirable manner provided the demanded current signal does not change so rapidly that the phase current becomes slew limited by the finite forcing voltage available. Under these circumstances either the on-time or the off-time become much longer than a usual switching period in order to change the value of the average current to a new demanded current level. This embodiment of the invention also works correctly provided the transition of the demanded current level is in a negative direction. In this case the on-time is very small as, after the off-time is over, the switches are fired and almost instantly turned back off again as there is too much current in the phase. However, when the transition is in the positive direction, the on-time becomes long. When this embodiment of the invention is used, a longer turn-off delay is produced which could cause the current substantially to overshoot the required current level. This condition will happen in practice at the start of every phase period, and additional control action is preferable to address this. Therefore, the system shown in Figure 8 limits the maximum turn-off delay whenever the on-time exceeds a given amount (e.g. a complete switching period).

[0040] This is implemented in Figure 8 by limiting the maximum count of the counter and can be achieved by any one of a number of known methods. Under very rapid dynamic conditions a good response from the controller is possible whilst, under steady-state or slowly varying conditions, the error between the demanded current and the actual phase current is substantially removed.

[0041] While the descriptions of the above implementations have been based on a power converter which uses only two states for the switch arrangement, those skilled in the art will recognise that it is equally possible to use the invention with a power converter which incorporates a 'freewheel' state in its switching sequence. While the actual parameter values for such an arrangement might differ from those described above, the same basic method applies.

[0042] It will also be evident that a digital implementation of the above embodiments of the invention could be made in a microprocessor or similar digital device as part of a larger overall control scheme. Such implementations are well-known to those skilled in the art.

[0043] The invention has been described in connection with the illustrated embodiments discussed above, those skilled in the art will recognise that many variations may be made without departing from the present invention. It will be appreciated that the circuits can be implemented in digital, analogue or a combination of digital and analogue arrangements. Accordingly, the above description of embodiments is made by way of example and not for the purposes of limitation. The present invention is intended to be limited only by the scope of the following claims.

Claims

1. A method of on-off control of a parameter of an electrical load, the method comprising:

   setting a demanded parameter value (i_d);
   applying a voltage across the load by actuating switch means (34) to initiate a changing parameter in the load; and
   removing the voltage from the load after a delay following the parameter reaching the demanded parameter value, such that the parameter exceeds the demanded value, the value of the error between the average parameter and the demanded value being reduced as a result, characterised in that the duration of the delay is derived from a period for which the voltage was previously applied across the load.

2. A method as claimed in claim 1, including:

   comparing a demand signal (i_d) indicative of the demanded parameter with a feedback signal (i_f) indicative of a load parameter to produce an output signal (i_e) having two possible states;
   producing a switch means deactuation signal in response to the output changing state; and
   delaying actuation of the switch means by the deactuation signal for the period of the delay.

3. A method as claimed in claim 1 or 2, including:

   generating a feedback signal (i_f) indicative of a parameter in a load;
   low-pass filtering the feedback signal; and
   comparing a demand signal (i_d) indicative of the demanded parameter value with the feedback signal to produce a switch means deactuation signal (i_t) in response to the feedback signal, thereby delaying actuation of the switch means by the deactuation signal.

4. A method as claimed in claim 1 including:

   determining the actuation period for which the switch means are actuated; and
   setting the deactuation period for which the switch means are subsequently deactuated in response to the actuation period.

5. A method as claimed in claim 4 in which the deactuation period is substantially equal to the actuation period.

6. A method as claimed in claim 4 or 5 in which the actuation period is determined by initiating one count in one direction from one value at the start of the actuation period and the deactuation period is set by initiating another count in the other direction from the value at the end of the one count to the one value.

7. A method as claimed in claim 4, 5 or 6, including:

   setting a desired actuation period;
   comparing the determined actuation period with the desired actuation period; and
   reducing the deactuation period if the determined actuation period exceeds the desired actuation period.

8. A method as claimed in claim 7, including reducing the deactuation period to a predetermined value.

9. An on-off controller for a parameter of an electrical load (12), the parameter having an instantaneous and an average value, the controller comprising:

> switch means (34) actuatable to control the supply of electrical power to the load;
> demand means for producing a parameter demand signal;
> means (14) for producing a parameter signal that is indicative of the instantaneous value of the parameter of the load;
> means (10) for deriving an error signal from the demand signal and the parameter signal;
> control means (20,22 ,36) arranged to receive the error signal and to produce one actuation signal for the switch means of a duration to reduce the error when the error signal exceeds a predetermined value and to produce another actuation signal for the switch means otherwise; and
> delay means (18) operable to delay the one actuation signal when the error signal exceeds the said predetermined value, the value of an error between the average parameter value and the value indicated by the parameter demand signal being reduced as a result of the delay, characterised in that the delay means are responsive to the duration of the other actuation signal to determine the period of the delay of the one actuation signal.

10. A controller as claimed in claim 9 in which the control means include a threshold detector, the said predetermined value being a threshold set in the threshold detector.

11. A controller as claimed in claim 10 in which the delay means are arranged to receive the output of the threshold detector to delay the one actuation signal.

12. A controller as claimed in claim 9, 10 or 11, including a comparator (10) arranged to receive the demand signal and the parameter signal to produce the error signal which is indicative of the difference between the demand and the parameter signals.

13. A controller as claimed in any of claims 9 to 12 in which the delay means include a low-pass filter (30) arranged to receive the parameter signal to cause it to lag the demand signal.

14. A controller as claimed in claim 9 in which the delay means are operable to set the duration of the one actuation signal substantially equal to the duration of the other actuation signal.

15. A controller as claimed in claim 9 or 14 in which the delay means include a counter (36) operable to count in one direction from a start value over the duration of the other actuation signal to an end value and to count in the other direction from the end value at the end of the other actuation period to the start value to determine the one actuation period.

Patentansprüche

1. Verfahren zur An-Aus-Steuerung eines Parameters einer elektrischen Last, umfassend:

> Einstellen eines erforderlichen Parameter-Werts (i_d);
> Anlegen einer Spannung an die Last durch Betätigen einer Schalteinrichtung (34), um einen Veränderungsparameter in der Last auszulösen; und
> Entfernen der Spannung von der Last nach einer Verzögerung, die dem Parameter, der den erforderlichen Parameterwert erreicht, folgt, so daß der Parameter den erforderlichen Wert übersteigt, wobei als Folge der Wert des Fehlers zwischen dem durchschnittlichen Parameter und dem erforderlichen Wert verringert wird, **dadurch gekennzeichnet,** daß die Dauer der Verzögerung von einer Zeitspanne, in der die Spannung vorher an die Last angelegt wurde, abgeleitet wird.

2. Verfahren nach Anspruch 1, welches einschließt:

> Vergleichen eines Bedarfssignals (i_d), bezeichnend für den erforderlichen Parameter mit einem Rückkopplungssignal (i_f), bezeichnend für einen Lastparameter zum Erzeugen eines Ausgabesignals (i_e), welches zwei mögliche Zustände besitzt;
> Erzeugen eines Abschaltsignals für die Schalteinrichtung als Reaktion auf den sich ändernden Zustand der Ausgabe; und
> Verzögern der Betätigung der Schalteinrichtung durch das Abschaltsignal für die Zeitdauer der Verzögerung.

3. Verfahren nach Anspruch 1 oder 2, welches einschließt:

> Erzeugen eines Rückkopplungssignals (i_f), bezeichnend für einen Parameter in einer Last; und
> Tiefpaßfiltern des Rückkopplungssignals;
> Vergleichen eines Bedarfssignals (i_d), bezeichnend für den erforderlichen Parameterwert in dem Rückkopplungssignal zum Erzeugen eines Abschaltsignals (it) für die Schalteinrich-

tung als Reaktion auf das Rückkopplungssignal, und damit Verzögern der Betätigung der Schalteinrichtung durch das Abschaltsignal.

4. Verfahren nach Anspruch 1, das einschließt:

   Festlegen des Betätigungszeitraums, in dem die Schalteinrichtung betätigt wird; und
   Einstellen des Abschaltzeitraums, in dem die Schalteinrichtung anschließend als Reaktion auf den Betätigungszeitraum abgeschaltet wird.

5. Verfahren nach Anspruch 4, in welchem der Abschaltzeitraum im wesentlichen gleich dem Betätigungszeitraum ist.

6. Verfahren nach Anspruch 4 oder 5, in welchem der Betätigungszeitraum bestimmt ist durch Auslösen eines Zählimpulses in einer Richtung von einem Wert am Beginn des Betätigungszeitraums, und der Abschaltzeitraum eingestellt ist durch Auslösen eines anderen Zählimpulses in die andere Richtung von dem Wert am Ende des einen Zählimpulses zu dem einen Wert.

7. Verfahren nach Anspruch 4, 5 oder 6, welches einschließt:

   Einstellen eines gewünschten Betätigungszeitraums;
   Vergleichen des bestimmten Betätigungszeitraums mit dem gewünschten Betätigungszeitraum; und
   Verringern des Abschaltzeitraums, wenn der bestimmte Betätigungszeitraum den gewünschten Betätigungszeitraum übersteigt.

8. Verfahren nach Anspruch 7, welches das Reduzieren des Abschaltzeitraums auf einen vorbestimmten Wert einschließt.

9. An-Aus-Steuergerät für einen Parameter einer elektrischen Last (12), wobei der Parameter einen momentanen und einen durchschnittlichen Wert besitzt, wobei das Steuergerät umfaßt:

   eine Schalteinrichtung (34) betätigbar zum Steuern der Versorgung der Last mit elektrischer Leistung;
   eine Bedarfseinrichtung zum Erzeugen eines Parameter-Bedarfssignals;
   eine Einrichtung (14) zum Erzeugen eines Parametersignals, das auf den momentanen Wert des Parameters der Last schließen läßt;
   eine Einrichtung (10) zum Ableiten eines Fehlersignals vom Bedarfssignal und dem Parametersignal;
   eine Steuereinrichtung (20, 22, 36), angeordnet, das Fehlersignal zu empfangen und ein Betätigungssignal für die Schalteinrichtung mit einer Zeitdauer zum Verringern des Fehlers, wenn das Fehlersignal einen vorbestimmten Wert übersteigt, und andernfalls zum Erzeugen eines anderen Betätigungssignals für die Schalteinrichtung zu erzeugen; und
   eine Verzögerungseinrichtung (18), die betrieben werden kann, das eine Betätigungssignal zu verzögern, wenn das Fehlersignal den vorbestimmten Wert übersteigt, wobei der Wert eines Fehlers zwischen dem durchschnittlichen Parameterwert und dem Wert, der durch das Parameter-Bedarfssignal angezeigt wird, als ein Ergebnis der Verzögerung reduziert wird, **dadurch gekennzeichnet, daß** die Verzögerungseinrichtung auf die Dauer des anderen Betätigungssignals reagiert, um die Zeitdauer der Verzögerung des einen Betätigungssignals zu bestimmen.

10. Steuergerät nach Anspruch 9, in welchem die Steuereinrichtung einen Schwellendetektor einschließt, wobei der vorbestimmte Wert eine im Schwellendetektor festgesetzte Schwelle ist.

11. Steuergerät nach Anspruch 10, in welchem die Verzögerungseinrichtung angeordnet ist, die Ausgabe des Schwellendetektors zu empfangen, um das eine Betätigungssignal zu verzögern.

12. Steuergerät nach Anspruch 9, 10 oder 11, das einen Komparator (10) einschließt, der angeordnet ist, das Bedarfssignal und das Parametersignal zum Erzeugen des Fehlersignals, das auf den Unterschied zwischen den Bedarfs- und den Parametersignalen schließen läßt, zu empfangen.

13. Steuergerät nach irgendeinem der Ansprüche 9 bis 12, in dem die Verzögerungseinrichtung einen Tiefpaßfilter (30) einschließt, der angeordnet ist, das Parametersignal zu empfangen, um es zu veranlassen, dem Bedarfssignal nachzufolgen.

14. Steuergerät nach Anspruch 9, in dem die Verzögerungseinrichtung betrieben werden kann, die Dauer des einen Betätigungssignals im wesentlichen gleich zu der Dauer des anderen Betätigungssignals einzustellen.

15. Steuergerät nach Anspruch 9 oder 14, in dem die Verzögerungseinrichtung einen Zähler (36) einschließt, der betrieben werden kann, in einer Richtung von einem Startwert über die Dauer des anderen Betätigungssignals zu einem Endwert zu zählen und in die andere Richtung von dem Endwert am Ende des anderen Betätigungszeitraums zum

Startwert zu zählen, um den einen Betätigungszeitraum zu bestimmen.

Revendications

1. Procédé de commande par tout ou rien d'un paramètre d'une charge électrique, le procédé comprenant:

   la définition d'une valeur de paramètre demandée (i_d) ;
   l'application d'une tension à travers la charge en activant des moyens de commutation (34) pour amorcer un paramètre changeant dans la charge, et
   l'élimination de la tension de la charge après un retard après que le paramètre a atteint la valeur de paramètre demandée, de sorte que le paramètre dépasse la valeur demandée, la valeur de l'erreur entre le paramètre moyen et la valeur demandée étant par conséquent réduite, caractérisé en ce que la durée du retard est dérivée d'une période pendant laquelle la tension était précédemment appliquée à travers la charge.

2. Procédé suivant la revendication 1, incluant:

   la comparaison d'un signal de demande (i_d) indiquant le paramètre demandé avec un signal de réaction (i_f) indiquant un paramètre de charge pour produire un signal de sortie(i_e) comprenant deux états possibles;
   la production d'un signal de désactivation de moyens de commutation en réaction au changement d'état de la sortie, et le retardement de l'activation des moyens de commutation par le signal de désactivation pendant la période du retard.

3. Procédé suivant la revendication 1 ou 2, incluant :

   la génération d'un signal de réaction (i_f) indiquant un paramètre dans une charge;
   le filtrage passe-bas du signal de réaction, et
   la comparaison d'un signal de demande (i_d) indiquant la valeur de paramètre demandée avec le signal de réaction pour produire un signal de désactivation de moyens de commutation (i_t) en réaction au signal de réaction, retardant de ce fait l'activation des moyens de commutation par le signal de désactivation.

4. Procédé suivant la revendication 1, incluant :

   la détermination de la période d'activation pendant laquelle les moyens de commutation sont activés, et
   la définition de la période de désactivation pendant laquelle les moyens de commutation sont ensuite désactivés en réaction à la période d'activation.

5. Procédé suivant la revendication 4, dans lequel la période de désactivation est pratiquement égale à la période d'activation.

6. Procédé suivant la revendication 4 ou 5, dans lequel la période d'activation est déterminée en amorçant un comptage dans une direction à partir d'une valeur au début de la période d'activation et la période de désactivation est définie en amorçant un autre comptage dans l'autre direction à partir de la valeur à la fin du un comptage jusqu'à la une valeur.

7. Procédé suivant la revendication 4, 5 ou 6, incluant :

   la définition d'une période d'activation souhaitée;
   la comparaison de la période d'activation déterminée avec la période d'activation souhaitée, et
   la réduction de la période de désactivation si la période d'activation déterminée dépasse la période d'activation souhaitée.

8. Procédé suivant la revendication 7, incluant la réduction de la période de désactivation à une valeur prédéterminée.

9. Régulateur tout ou rien pour un paramètre d'une charge électrique (12), le paramètre comprenant une valeur instantanée et une valeur moyenne, le régulateur comprenant :

   des moyens de commutation (34) pouvant être activés pour commander l'alimentation d'énergie électrique à la charge;
   des moyens de demande pour produire un signal de demande de paramètre;
   des moyens (14) pour produire un signal de paramètre indiquant la valeur instantanée du paramètre de la charge;
   des moyens (10) pour dériver un signal d'erreur du signal de demande et du signal de paramètre;
   des moyens de commande (20, 22, 36) propres à recevoir le signal d'erreur et à produire un signal d'activation pour les moyens de commutation d'une durée pour réduire l'erreur lorsque le signal d'erreur dépasse une valeur prédéterminée et pour, dans le cas contraire, produire un autre signal d'activation pour les moyens de commutation, et
   des moyens de retard (18) pouvant fonctionner

pour retarder le un signal d'activation lorsque le signal d'erreur dépasse ladite valeur prédéterminée; la valeur d'une erreur entre la valeur de paramètre moyenne et la valeur indiquée par le signal de demande de paramètre étant réduite à la suite du retard, caractérisé en ce que les moyens de retard réagissent à la durée de l'autre signal d'activation pour déterminer la période du retard du un signal d'activation.

10. Régulateur suivant la revendication 9, dans lequel les moyens de commande comprennent un détecteur de seuil, ladite valeur prédéterminée étant un seuil défini dans le détecteur de seuil.

11. Régulateur suivant la revendication 10, dans lequel les moyens de retard sont propres à recevoir la sortie du détecteur de seuil pour retarder le un signal d'activation.

12. Régulateur suivant la revendication 9, 10 ou 11, incluant un comparateur (10) propre à recevoir le signal de demande et le signal de paramètre pour produire le signal d'erreur indiquant la différence entre les signaux de demande et de paramètre.

13. Régulateur suivant l'une quelconque des revendications 9 à 12, dans lequel les moyens de retard comprennent un filtre passe-bas (30) propre à recevoir le signal de paramètre pour l'amener à rester à la traîne du signal de demande.

14. Régulateur suivant la revendication 9, dans lequel les moyens de retard peuvent fonctionner pour définir la durée du un signal d'activation pratiquement égale à la durée de l'autre signal d'activation.

15. Régulateur suivant la revendication 9 ou 14, dans lequel les moyens de retard comprennent un compteur (36) pouvant fonctionner pour compter dans une direction à partir d'une valeur de début sur la durée de l'autre signal d'activation jusqu'à une valeur de fin et pour compter dans l'autre direction à partir de la valeur de fin au terme de l'autre période d'activation jusqu'à la valeur de début pour déterminer la une période d'activation.

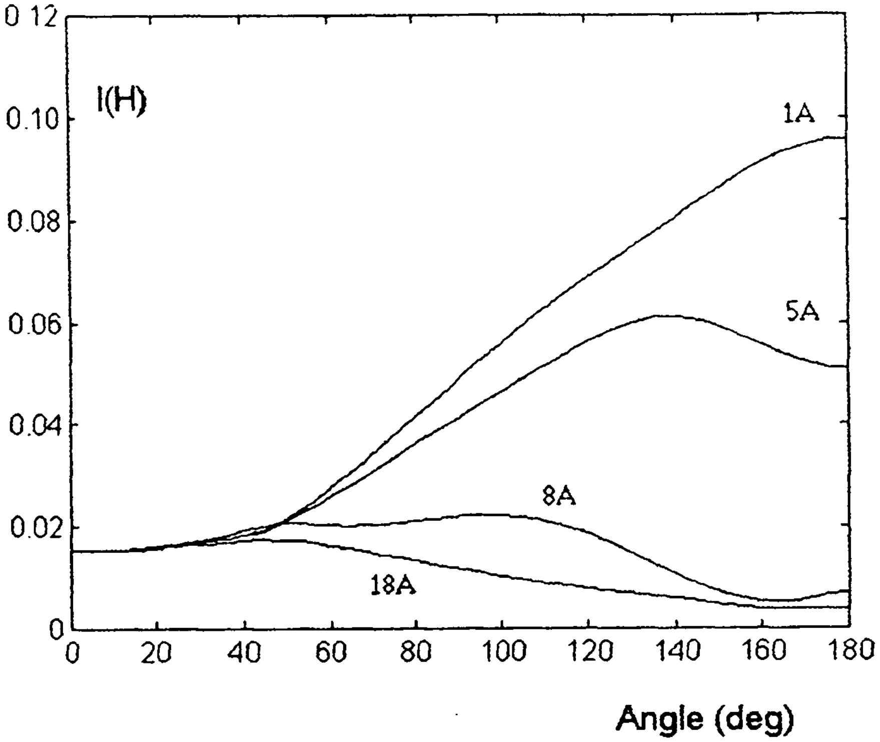
I(H)
1A
5A
8A
18A
0.12
0.10
0.08
0.06
0.04
0.02
0
0
20
40
60
80
100
120
140
160
180
Angle (deg)

Fig 1

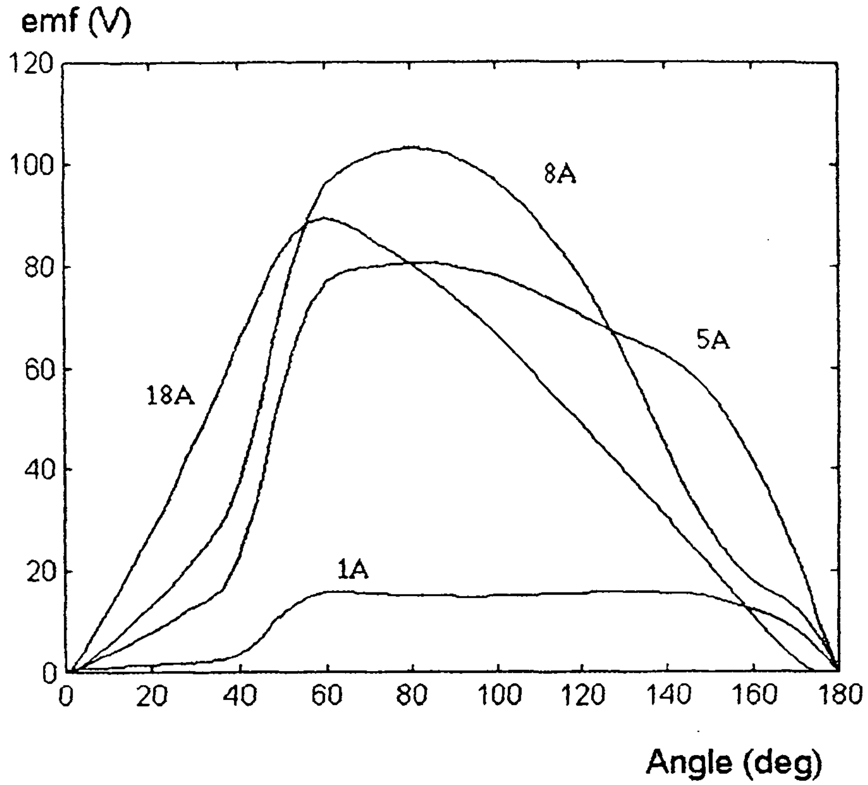
emf (V)
120
100
80
60
40
20
0
0
20
40
60
80
100
120
140
160
180
Angle (deg)
8A
5A
18A
1A

Fig 2

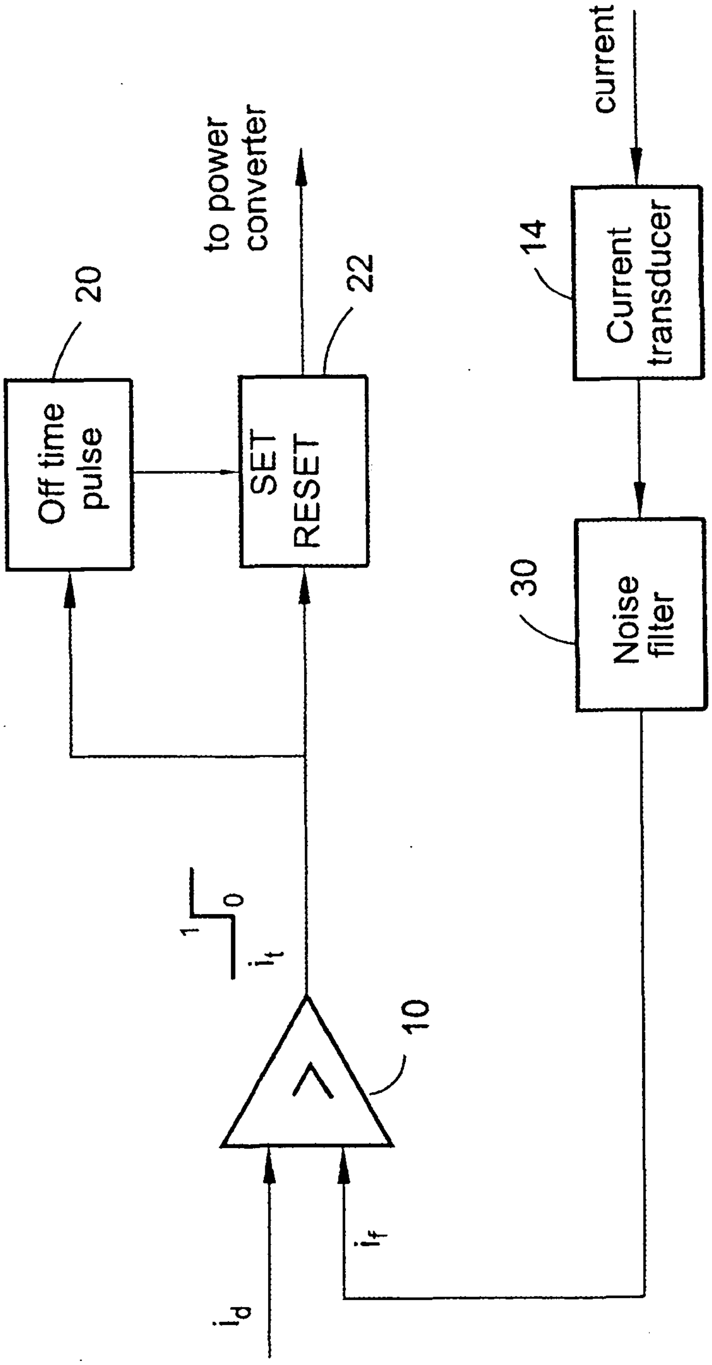

Fig 3
Prior Art

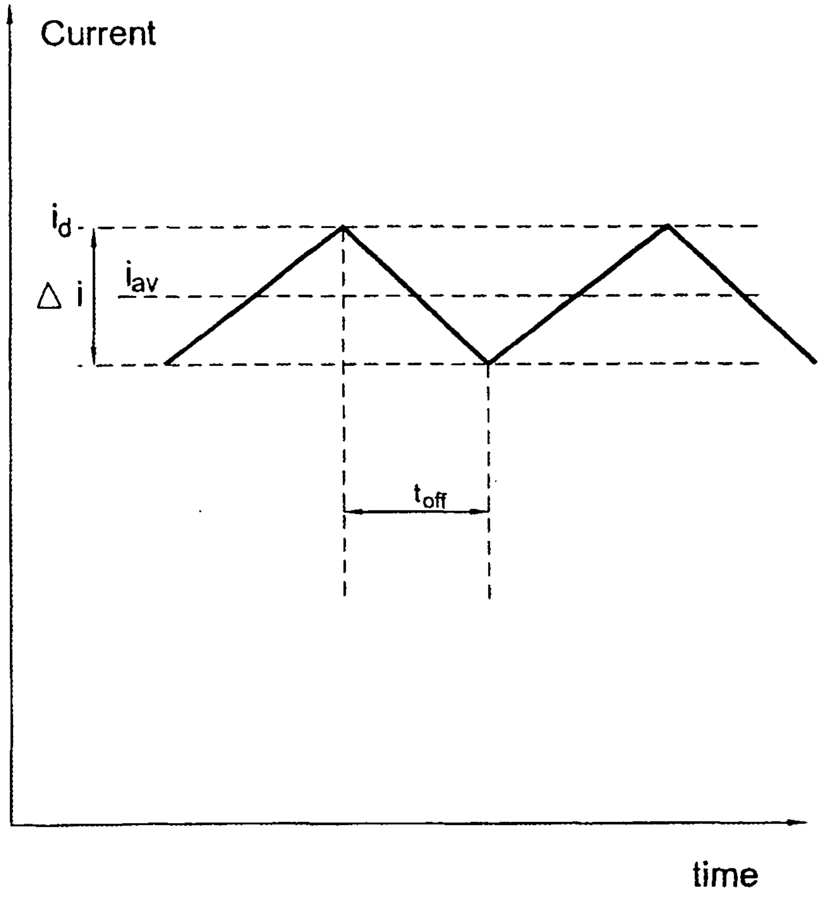

Fig 4

Prior Art

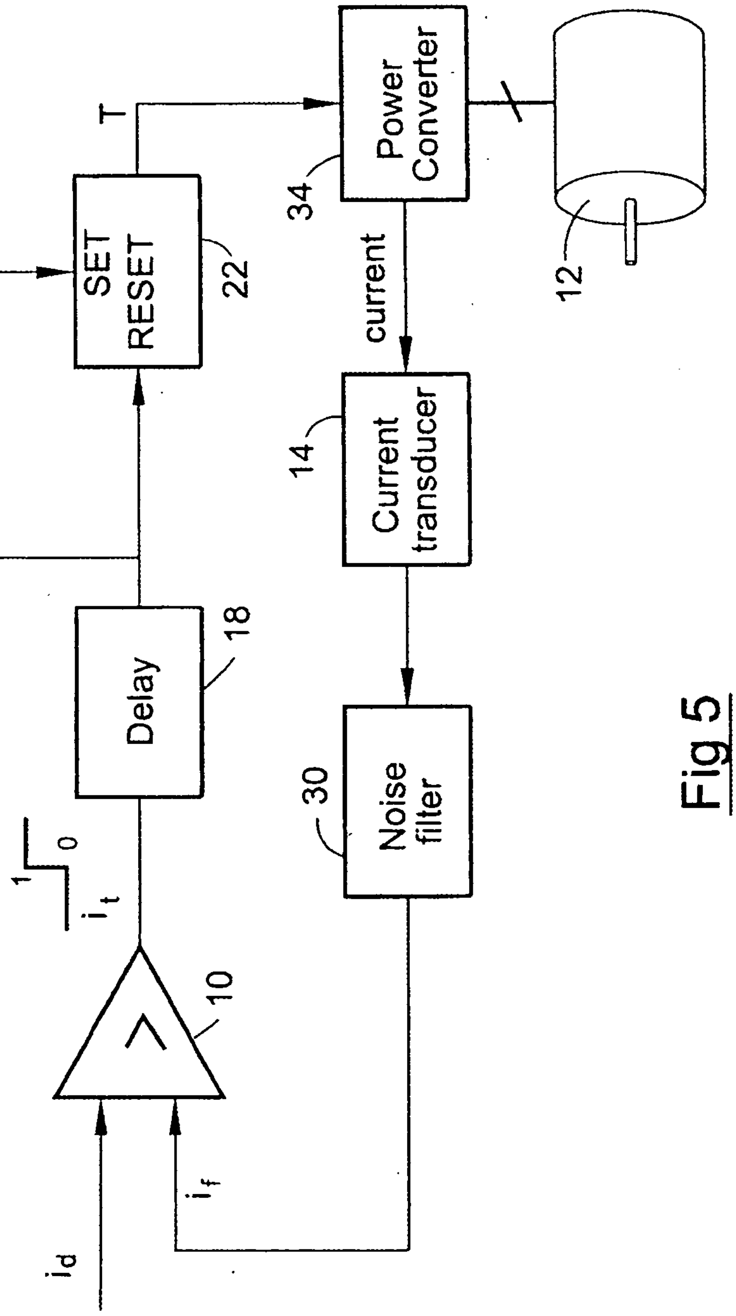
Off time pulse
20
SET
RESET
22
T
Power Converter
34
12
current
Current transducer
14
Delay
18
Noise filter
30
1
0
i_t
>
10
i_d
i_f

Fig 5

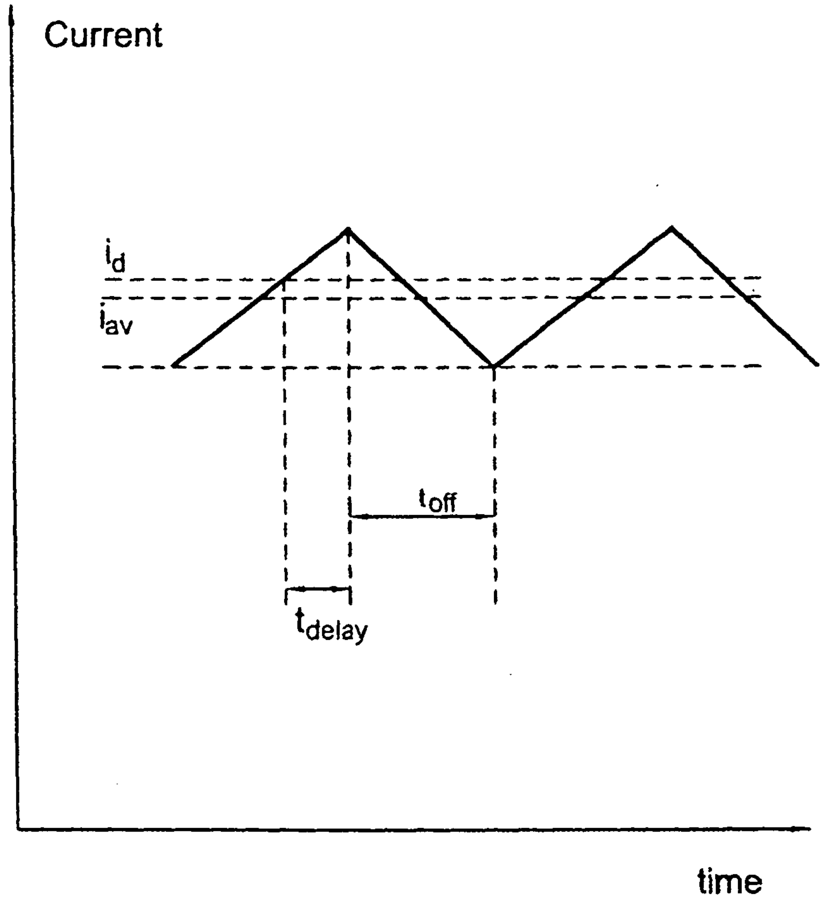

Fig 6

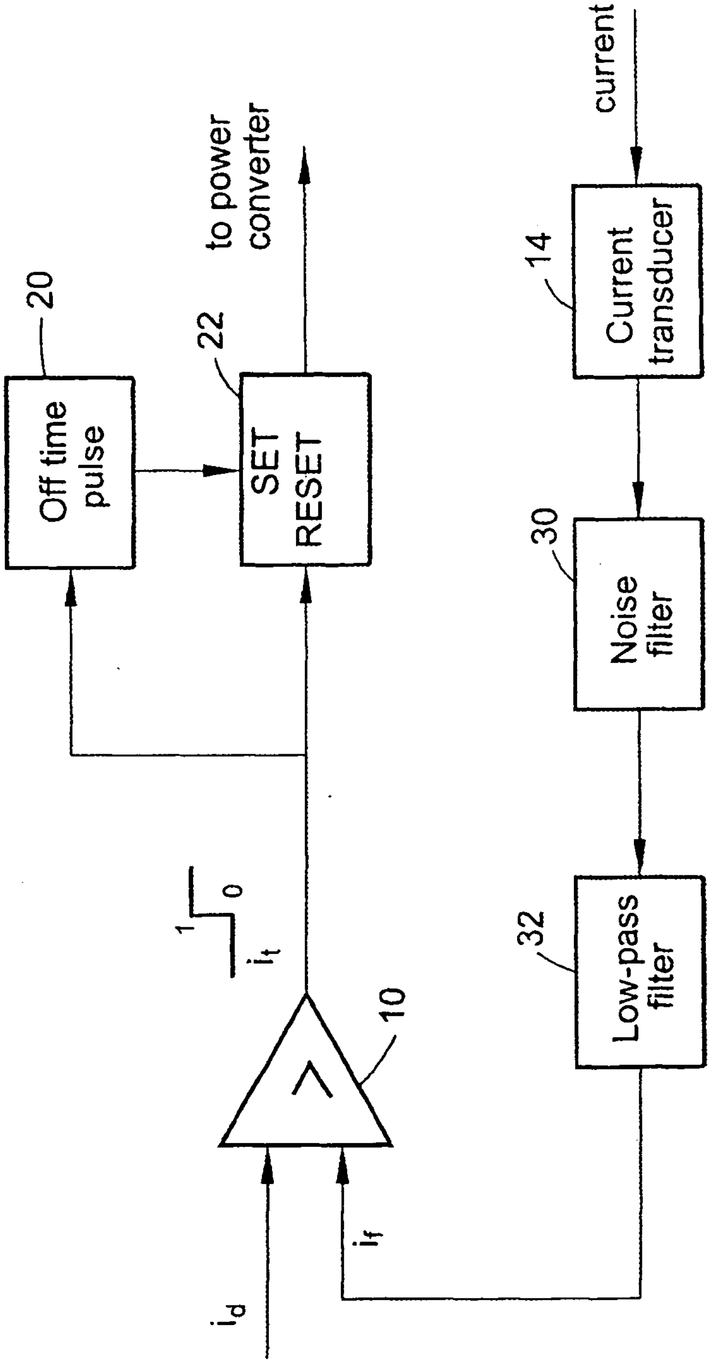
Off time pulse
20
SET
RESET
22
to power converter
1
0
i_t
10
i_d
i_f
current
Current transducer
14
Noise filter
30
Low-pass filter
32

Fig 7

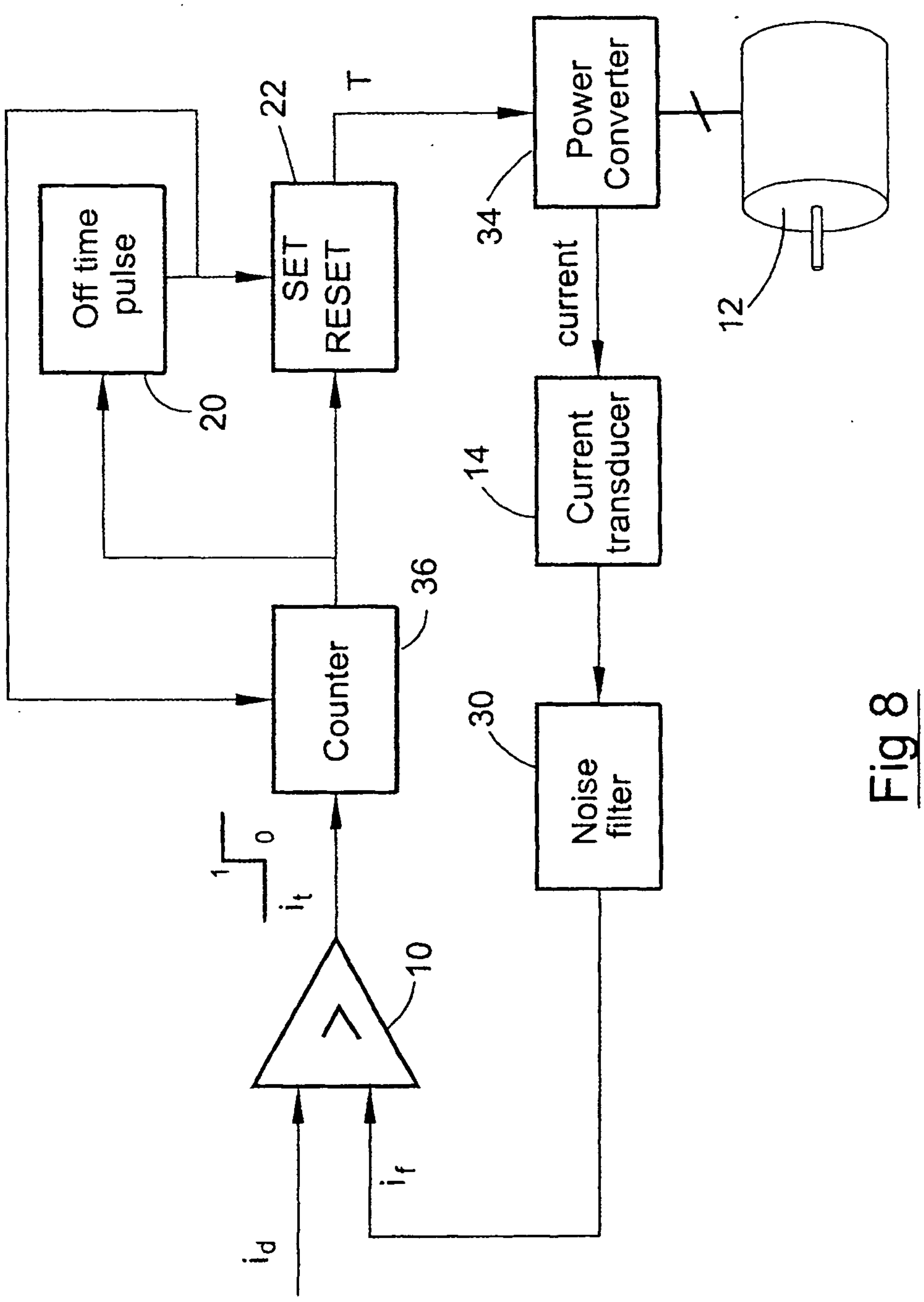
Off time pulse
20
SET RESET
22
T
Power Converter
34
current
12
Current transducer
14
Counter
36
Noise filter
30
1
0
i_t
10
i_d
i_f

Fig 8